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(54) **Composite reinforced electrical transmission conductor**

(57) A composite reinforced electrical transmission conductor cable primarily designed for transmission of electrical signals, such as data signals, telephone signals of any frequency and electrical power of essentially any voltage. A fiber optic cable may also be carried by the core in a preferred embodiment. A splicing arrangement for securing the ends of the cable together is also provided. The cable is comprised of a reinforced plastic composite component which serves as a load bearing component and an electrically conductive component which serves for transmission of the electrical signals carried by the cable. In a preferred embodiment, the cable is comprised of a reinforced plastic composite outer load carrying sheath along with an inner highly electrically conductive core. In this way, the sheath provides the necessary strength and the inner core provides for transmission of the electrical signals. In still further embodiments, strips of reinforcd plastic composite can be embedded in an electrically coductive cylindrically shaped cable material.

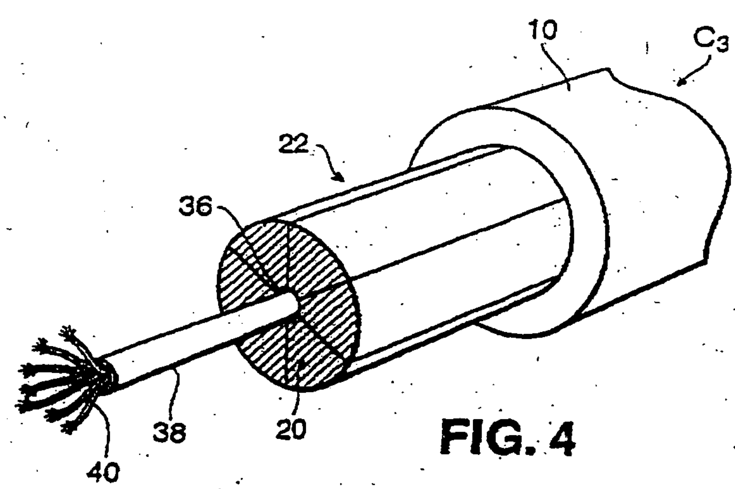

FIG. 4

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] This invention relates in general to certain new and useful improvements in electrical transmission cables and, more particularly, to electrical transmission cables which have a composite reinforced component to provide loading capabilities and alternatively which permits the introduction of fiber optic filaments as an integral part of the transmission cable.

[0002] It has been realized that it would be desirable to provide a cable construction with an inner core as the electrical current carrying component formed of smelted aluminum or other highly conductive materials, such as copper, silver, etc. Although these metal cores have excellent electrical conductivity, they do not possess good load carrying properties and, hence, it is possible to use such inner core materials by taking advantage of the increased conductivity with an outer composite shell providing the load carrying component. By use of this construction, and since the amount of composite material can be the same as or greater than the amount carried in a central core cable construction, the same or increased strength capability is provided.

[0003] With cable of the present invention, not only is an increase in conductivity exploited, but there is a substantial advantage in lower weight for a given cable diameter. This is due to the fact that the same weight of composite material can be distributed as an outer shell and which would be relatively thin in cross section compared to a composite center core. Moreover, this construction reduces the heating and subsequent energy loss, as well as the line sag which occurs with the stranded steel cable member. In addition, the use of the aluminum core composite allows the advantage of greater conductivity from use of smelted aluminum versus the alloyed aluminum.

[0004] Another one of the significant problem involved in the transmission and distribution of communication signals is that of transmitting fiber optic signals. The transmission and distribution of fiber optic signals is relatively new and, as a result, right of ways for support poles to hold the fiber optic cables are very limited, if not virtually non-existent. At present, most of the fiber optic cables are wrapped about electrical transmission conductors in a rather rudimentary fashion. This system eliminates the need for condemnation of land, easements and construction of new transmission poles. Moreover, underground cable also presents environmental concerns. As a result, and even though rudimentary, fiber optic cables are presently wrapped about electrical transmission conductors.

[0005] The fiber optic cables when carried by electrical transmission conductors suffer the environmental effects of weathering, ultraviolet radiation, and the like. It would, of course, be desirable to combine the transmission of fiber optic signals with that of the electrical signals in order to effectively combine a transmission grid into a transmission-communication grid.

BRIEF SUMMARY OF THE INVENTION

[0006] The present invention relates in general to electrical current carrying conductors which utilize an outer load bearing component formed of a reinforced plastic composite material as well as a central core serving as an electrical current carrying conductor and formed of a highly electrically conductive current carrying material. The cables of the present invention have an elongate continuous central bore extending therethrough for carrying fiber optic cables or other type of communication cables. In this way, the cables of the invention not only provide for power transmission and distribution but they also provide for communication transmission and distribution, thereby forming a combined transmission grid of power and communication signals.

[0007] As indicated previously, and in its simplest form, one of the major objects of the invention was to provide an electrical current carrying cable that would take advantage of the fact that pure smelted-aluminum has at least 10% greater conductivity than an alloyed aluminum. The cable of the present invention also adds the advantage that it is capable of carrying communication signals, such as fiber optic bundles, for telecommunication. Notwithstanding and in accordance with the invention, it is no longer necessary to use the aluminum as a major portion of the load carrying capability in a final cable and, hence, it is no longer necessary to alloy that aluminum for enhancement of tensile properties. Since the aluminum in the present invention is not being used for load carrying capabilities, it can remain as smelted aluminum with virtually no physical properties for that purpose. The load carrying capability is provided by the reinforced plastic composite outer sheath of the cable. The higher conductivity of the smelted aluminum can them be used to its fullest advantage.

[0008] Inasmuch as the same amount of composite material can be used when the composite surrounds the central aluminum core, as would be the case when the composite constitutes the central core, the composite can actually be used in a much thinner cross section. Thus, there is a substantially lower weight for any given cable diameter. This coupled with the reduction in heating and subsequent energy loss tends to be a highly effective cable. Moreover, inasmuch as there is a weight reduction, line sag, which occurs with a standard steel cable, has been reduced.

[0009] By using an outer composite jacket as part of the current carrying cable, this jacket provides both water protection for the center aluminum core and, moreover, reduces the exposure of the aluminum core to other weathering and environmental conditions. It further insulates the communications cable, such as the fiber

optics cable, from exposure to environmental conditions. In addition, the cable of the invention is effective in achieving security of messages transmitted over the fiber optic cables, in that the location of the cable makes it difficult for access.

[0010] It can be seen from the above that some of the specific advantages of the composite reinforced aluminum cable of the invention is that:

1. The cost of the composite reinforced conductor is equal to or less than the cost of the traditional steel cable conductor of the same diameter.
2. The cable of the present invention allows for the carrying of communication conductors and, particularly, fiber optic cable, such that the conductor system of the invention allows for a combined power delivery and communication delivery grid.
3. The composite materials used as the outer sheath have a coefficient of thermal expansion which is fifty percent less than the steel core reinforcement.
4. The tensile strength (breaking strength) is about one hundred fifty percent higher than carbon steel core wire (with HC steel being approximately 210ksi).
5. Conductivity of composite reinforced conductors is at least forty percent higher and having a target value of as much as two hundred percent higher than steel reinforced aluminum conductors (ACSR conductors) of the same outer diameter.
6. The present conductor cables are also capable of utilizing T&D accessories and other accessories which are installed in a similar manner in traditional cable.
7. The present conductor cables have the capability of being used with field installation equipment and procedures which exist with minimum modifications.
8. The composite materials are compatible with conventional wire and cable process technology.
9. The cables of the invention eliminate eddy-current heating.
10. A solid aluminum core has 1/100 degree of radial temperature differences as compared to stranded wire.
11. There is no loss of strength in the present cable and consequent increase in sag due to annealing of the tension member.
12. The cable of the invention has simplified manufacturing requirements because there is no need for multiple layers of stranded aluminum in order to cancel out self-inductance.
13. There is an elimination of non-uniform current flow due to self-inductance when using the instant conductor cable.

[0011] In addition to the other advantages, the new conductor of the present invention has at least twice the recycling effectiveness as does the ACSR. The existence of this new cable along with commercial manufacturing processes allows for core extrusion and composite pultrusion processes to be used in combination in a continuous high speed, low cost, mass production assembly line. The process also converts aluminum into a high value added product by producing and integrating a lightweight composite material strength member and an optical fiber for data transmission and intelligence monitoring.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Having thus described the invention in general terms, reference will now be made to the accompanying drawings in which:

Figure 1 is a fragmentary perspective view of a composite reinforced current carrying conductor with an inner electrically conductive core construction in accordance with and embodying the present invention;

Figure 2 is a fragmentary perspective view, similar to Figure 1, and showing an outer composite reinforced load carrying conductor in fully cured state and with an inner electrically conductive core in accordance with the present invention;

Figure 3 is a fragmentary perspective view showing still a further modified form of composite reinforced current carrying conductor cable with an inner electrically conductive segmented core in accordance with the present invention;

Figure 4 is a fragmentary perspective view of yet another modified form of composite reinforced current carrying conductor in accordance with the present invention and containing the fiber optic cable bundle carried thereby;

Figure 5 is a fragmentary perspective view, similar to Figure 4, and showing portions of the core spread apart to accept a fiber optic cable;

Figure 6 is a fragmentary perspective view showing another modified form of composite reinforced current carrying conductor in accordance with the present invention;

Figure 7 is a fragmentary perspective view showing still another modified form of electrical current carrying conductor having an inner electrically conductive core and outer composite load carrying sheath, except that cooling fluid ducts are formed in the outer sheath;

Figure 8 is a fragmentary perspective view showing still another modified form of electrical current carrying conductor in which the current carrying material is also provided with helical strips of load bearing reinforced composite material;

Figure 9 is a fragmentary sectional view showing the first step in splicing of a cable in accordance with the present invention;

Figure 10 is a fragmentary sectional view similar to Figure 15 and showing the second step in the splicing of cables;

Figure 11 is a fragmentary sectional view similar to Figures 9 and 10 and showing the step of splicing a fiber optic cable in the splicing of cables of the type shown in Figures 1-5;

Figure 12 is a fragmentary schematic sectional view similar to Figure 11 and showing the completed spliced cable;

Figure 13 is a sectional view taken along line 13-13 of Figure 12;

Figure 14 is a fragmentary perspective view showing yet another modified form of electrical current carrying conductor in accordance with the present invention;

Figure 15 is an end sectional view taken through a diameteral cross-section of another modified form of electrical current carrying cable constructed in accordance with and embodying the present invention; and

Figure 16 is a fragmentary perspective view of still a further modified form of cable constructed in accordance with the present invention and which is similar to Figure 8, but also carrying a fiber optic cable bundle therewith.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0013] Referring now in more detail and by reference characters to the drawings, which illustrate preferred embodiments of the present invention, C_1 illustrates an electrical transmission cable having a reinforced plastic composite load bearing outer sheath 10 and a central electrically conductive aluminum core 12 extending therethrough. By further reference to Figure 1, it can be seen that the load bearing sheath 10 is a tubular reinforced plastic composite member. Also, in the embodiment as illustrated in Figure 1 and the subsequently illustrated and described embodiments, there is a single core material, although the core may be formed of a plurality of individual aluminum layers. It should also be understood that the aluminum core could be formed of stranded wire. It can be observed that in this construction, the cable C_1 is similar in appearance to a conventional steel core cable. Consequently, it can be laid in the same fashion or suspended in the same fashion and using the same equipment as that employed for a steel core cable.

[0014] The outer sheath 10 is initially comprised of individual windings or rovings of reinforcing materials, also as hereinafter described. As shown, helically wound strands, including both clockwise wound strand and counterclockwise wound strands, or otherwise other pattern combinations of wound strands, are applied to the central core in a desired thickness.

[0015] The winding of the individual strands of reinforcing material may be accomplished by any of a number of known winding systems and include, for example, those apparatus described in U.S. Patent No. 3,579,401 to William Brandt Goldsworthy, et al, U.S. Patent No. 3,769,127 to William Brandt Goldsworthy, et al, U.S. Patent No. 3,810,805 to William Brandt Goldsworthy, et al, U.S. Patent No. 3,576,705 to William Brandt Goldsworthy, et al, and U.S. Patent No. 3,654,028 to Goldsworthy, as well as numerous other patents to Goldsworthy.

[0016] The embodiment of Figure 1 is primarily effective for only short length cables. This is due to the fact that the core 10 is not capable of significant bending. It may be appreciated that the entire cable must be capable of being wound about a drum and transported for a substantial distance where it would then be unwound from the drum and either suspended or laid at a site of use. For this purpose, the central core 10 is preferably formed of a plurality of individually shaped core sections 20, as best shown in the cable C_2 of Figure 3. In this particular case, the individual sections 20, when assembled together, create a cylindrically shaped core 22. By winding the strands about the central core in one direction enables some slippage of the strands relative to one another so that winding of the cable about a drum or other cylindrically shaped member is facilitated.

[0017] In the embodiment of the invention as shown in Figure 2, six individual pie-shaped sections are provided. However, any number of section could be provided. In connection with the present invention, it has been found that the five individual sections are preferred inasmuch as this is the number of sections which allow for a bending of the cable and a winding of the cable about a spool and which nevertheless do not create an unduly large number of sections forming the cable.

[0018] It has also been found in accordance with the present invention that it is desirable to have an odd number of individual sections as, for example, five, seven or nine individual sections. This odd number of individual sections facilitates the wind of the cable about a storage drum or the like for purposes of winding and transportation on a truck or otherwise.

[0019] Figure 4 illustrates an embodiment of a cable C_3 similar to the cable C_2, except that in this particular case, the individual pie-shaped sections 20 of the core 22 are formed with an arcuately shaped recess 34 formed at their inner most ends. In this particular embodiment, the inner most ends 34, as shown in Figures 5 and 6 are generally trapezoidal in shape. The fact that there are individual segments, such as those shown, allows for the cable to be wound upon a winch or like structure.

[0020] It also can be observed that the innermost ends 34 define a central aperture 36 which receives a fiber optic cable bundle 38 having individual fiber optic cables 40.

[0021] Figure 6 illustrates an embodiment C_4 in which there are two semi-circular sections 52 and 54 and each

of which have semi-circular openings 56 to define a central bore for receiving a fiber optic cable 38. One of the sections 52 has projecting elongate prongs 60 which are adapted to fit within elongate slots 62 of the other half conductor 54.

[0022] Figure 7 illustrates an embodiment C_5 in which there is a cable 70 having a plurality of coolant ducts 72 for receiving a cooling fluid, such as water or an oil or the like, and which is designed to remove heat generated through the current passing through the electrical current carrying conductor.

[0023] Figure 8 illustrates an embodiment in which there is not an outer cylindrically shaped core formed of a reinforced plastic material. Rather, there is a metallic core 74 having a plurality of helically wound slots 76 formed on the surface of the core and which is designed to receive reinforced plastic composite strips 78.

[0024] Figure 16 illustrates an embodiment which also uses a central core 74 and individual strips 160. Moreover, this embodiment C_7 is provided with a central bore having a fiber optic cable bundle 162 extending therethrough.

[0025] Figure 14 illustrates an embodiment of a cable C_8 in which there are a plurality of fiber optic bundles 172 having individual fiber optic cables 174 and surrounded by a metallic current carrying conductor 166 having a space 168 to receive the fiber optic cables 170. This, in turn, is provided with outer individual spiral strips 176 of a reinforced composite load bearing member forming an outer sheath 180. In addition, yet another outer sheath 182 is disposed about the sheath 176.

[0026] Figure 15 illustrates an embodiment C_9 in which there is a segmented core 190 formed of individual segments 192 made of a highly electrically conductive material, such as aluminum or the like. In addition, the core is surrounded on its periphery by individual preformed composite segments 194, as shown. These segments do not interlock with one another but are closely spaced apart from the next adjacent segment. If desired, they could interlock, but in the embodiment as shown, the individual segments permit relatively easy slippage with respect to one another thereby allowing the cable to be easily wound.

[0027] In the embodiment of the invention as shown in Figure 15, the various composite segments 194 are covered by an outer sheath 196 similar to the sheath 182 in the embodiment C_8. This embodiment of the invention has also been found to be equally effective, in that the outer sheath 196 aids in protecting the cable from weathering conditions and other environmental degradation. The inner core 190 is also provided with a central bore 198 to receive a fiber optic cable or other communication cable (not shown).

[0028] Figures 9-13 illustrate an embodiment of splicing any of the previously described electrical current carrying cables C_1-C_9.

[0029] In the splicing technique as shown in Figures 9-13, it can be observed that an electrical current carrying conductor 120, similar to any of the previously described current carrying cables, is to be spliced to a similar axially aligned current carrying conductor 122, the later of which is also similar to any of the previously described current carrying cables. Each of these electrical current carrying cables 120 and 122 are each provided with inner cores 124 and 126, respectively, formed of a highly conductive electrical material, such as aluminum. Moreover, each of the inner cores 124 and 126 carry fiber optic cables 128 and 130. Finally, each of the electrical cables 120 and 122 are provided with outer reinforced plastic composite load bearing sheaths 134 and 136, respectively.

[0030] As indicated previously, each of the electrical cables 120 and 122 are wound upon spools of the cable at a production site and transported to a site of use, which may be at a remote location. At that point, the individual cables are then unspooled and must be spliced together in discrete lengths. As also indicated previously, splicing of the fiber optic cables must take place at a separate fiber optic cable splicing station, as shown schematically at 138 in Figure 12. The technique of splicing fiber optic cables is conventional and is therefore neither illustrated nor described in any further detail herein.

[0031] In order to splice the individual lengths of cables 120 and 122 together, the outer composite sheaths surrounding the central current carrying conductors 124 and 126 are literally severed from the remaining portions of the outer sheaths and removed in order to expose the ends of the conductors 124 and 126, as best shown in Figure 9. Thereafter, an electrically conductive compression sleeve 140, also formed of the same material as either of the cores 124 and 126, is slid over the end of one of the cables, such as the core 126 of the cable 122. In addition, an outermost reinforced plastic composite bonding sleeve 142 is also slid over the end of the cable 122 before separation of the reinforced plastic composite outer load bearing layer 136. At this point, the two cables 120 and 122 are then in a position where they can be spliced.

[0032] In the actual splicing, the two cables 120 and 122 are brought together, such that the cores 124 and 126 are located in abutting engagement. Thereafter, the compression sleeve 140 is actually shifted to extend over the end regions of each of the two cores 124 and 126, in the manner as shown in Figures 10 and 11. At this point, the compression sleeve may then be physically secured to the ends of the two cores 124 and 126, in the manner as shown in Figures 10-12. At this point in the splicing process, the reinforced plastic composite outer sheaths 134 and 136, which have then be removed, are replaced by the outer reinforced plastic composite sleeve 142. This outer bonding sleeve 142 is axially shifted over or abut against end portions of each of the outer sheaths 134 and 136. At this point, a heater (not shown) is employed for heating the reinforced plastic composite materials and pressure is applied so that

the outer bonding sleeve 142 and the end portions of the sheaths 134 and 136 will partially liquefy and again flow together to form an integral bonding thereof. The pressure may be applied by hand operated tools, such as tools in the nature of a pair of pliers. The pressure itself is used to consolidate the material and drive out any entrained air during the curing of the resin matrix material. In this way, it can be observed that the two major components of one cable are easily spliced to the corresponding components of the opposite cable.

[0033] Figures 12 and 13 also illustrate the individual components of the spliced section showing a completed splice so as to enable splicing of any of those electrical current carrying cables C_5-C_9.

[0034] The electrical transmission cables of the invention also are adapted to carry more electrical current then a comparably sized steel core conductor. This is due to the fact that more of the highly conductive metal, such as aluminum, is capable of being carried with a reinforced plastic sheath then would be carried with a similarly sized steel cable with no weight increase and even some weight decrease.

Claims

1. An electrical current carrying conductor cable for transmission of electrical current, said current carrying conductor cable having a load carrying component and an electrical current carrying component, an improvement comprising:

   a) said load carrying component formed of a reinforced composite material; and
   b) said electrical current carrying component being a highly conductive current carrying component.

2. The electrical current carrying conductor cable of Claim 1 wherein said load carrying component is an outer sheath which is comprised of a reinforced plastic composite material and completely surrounds the other of said components.

3. The electrical current carrying conductor cable of Claim 1 wherein said highly conductive current carrying component is comprised of a plurality of individual sections which are physically abutted together for purposes of enabling the cable to be placed over a curved surface, and which individual sections are concentrically arranged to form a cylindrically shaped conductor.

4. The electrical current carrying conductor of Claim 1 wherein a communication cable is carried in a bore formed in said highly conductive electrical current carrying component.

5. The electrical current carrying conductor cable of Claim 4 wherein said current carrying component is a central core formed of individual sections and each of which are somewhat trapezoidal shaped and form a central bore sized to receive a fiber optic cable.

6. The electrical current carrying conductor cable of Claim 1 wherein said electrical current carrying component is a core surrounded by said load carrying component and carries a fiber optic cable therein.

7. The electrical current carrying conductor cable of Claim 6 wherein said central core is comprised of a plurality of individual sections which are concentrically arranged to form a cylindrically shaped electrical conductor, said individual sections being shaped to form a central bore sized to receive a fiber optic cable.

8. A method of producing a long distance transmission current carrying cable in which the method comprises providing a generally cylindrically shaped central core, and locating an outer cylindrically shaped sheath around said core; an improvement comprising:
   a) one of said core or sheath being comprised of a highly conductive electrical current carrying material and the other being comprised of a reinforced plastic composite material which provides load carrying capability to said cable.

9. The method for producing a transmission current carrying cable of Claim 8 wherein said method comprises forming said core of a plurality of individual sections brought together to form a cylindrically shaped inner core.

10. The method for producing a transmission current carrying cable of Claim 9 wherein said method comprises of providing the central bore in the current carrying conductor and the method further comprises carrying a fiber optic cable in the central bore.

11. The method of Claim 10 wherein said method further comprises:

    a) locating an inner sleeve formed generally of the same material as said core about a first of the cables;
    b) locating an outer sleeve on a second of said cables generally formed of the same material as said outer sheath about a second of said cables;
    c) abutting the end of the inner core of a first cable against the end of an inner core of a second of the cables to be spliced so that each are

generally axially aligned;

d) compressing the sleeve about the abutted ends of the first and second cables so that the two cables are secured to one another in electrically conductive relationship;

e) locating the second sleeve about the abutted ends of the first and second cables;

f) heating said outer sleeve when in engagement with the ends of the individual outer sheaths to cause a resin impregnated in the sheaths and the outer sleeve to partially liquefy and effectively flow around the corresponding ends; and

g) allowing the resin to cool thereby permanently bonding the outer sheath of the first cable to the outer sheath of the second cable.

12. The method of splicing cables of Claim 11 wherein said method comprises:

a) axially shifting the second bonding outer sleeve formed generally of the same material as said sheath about said joined ends of said cables when abutting the ends of the inner cores;

b) heating said bonding sleeve and integrally bonding it to said ends of said sheaths.

13. The method of splicing cables of Claim 12 wherein said method also comprises splicing the ends of a fiber optic cable carried in the core of each of the individual first and second cables.

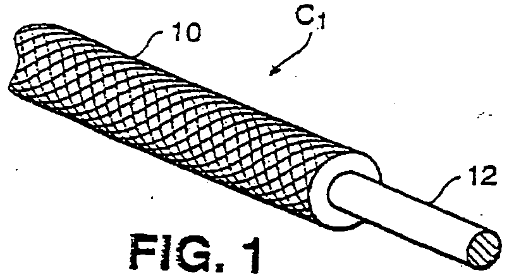

FIG. 1

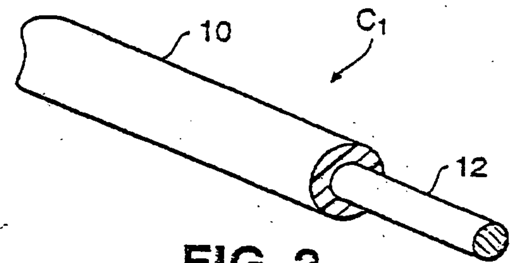

FIG. 2

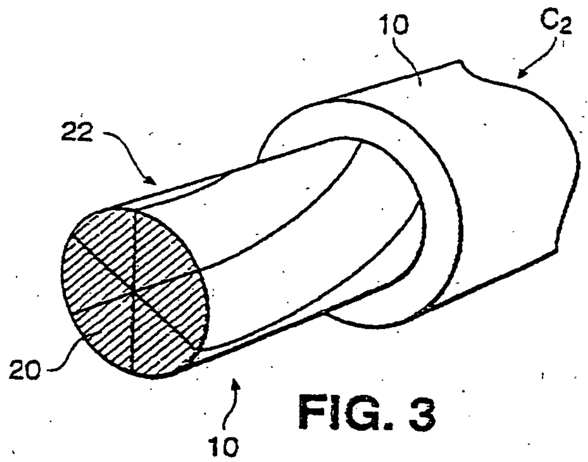

FIG. 3

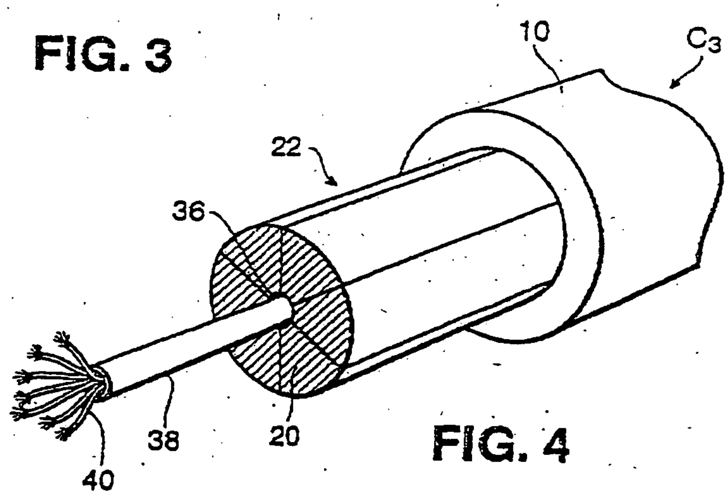

FIG. 4

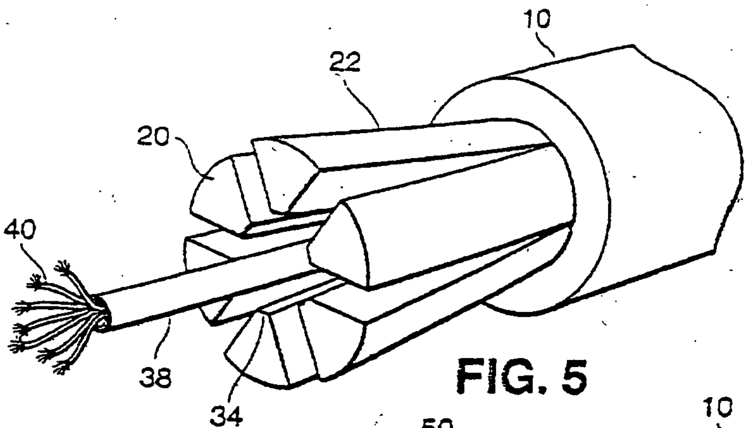

FIG. 5

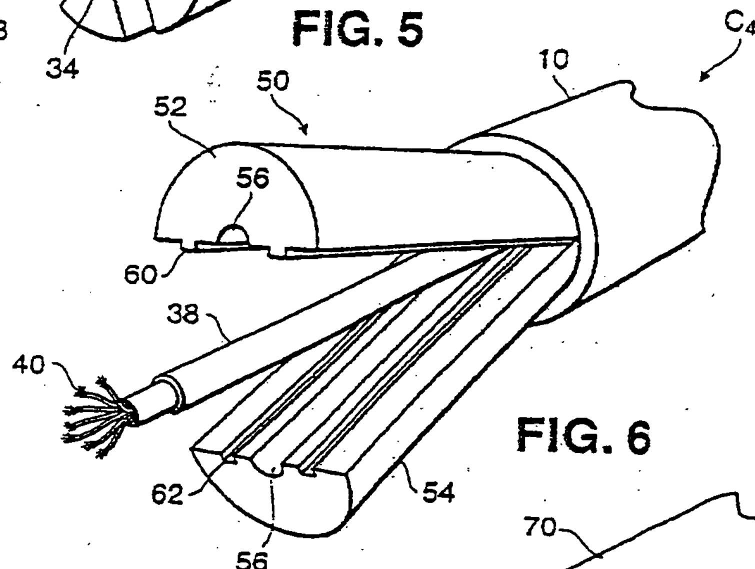

FIG. 6

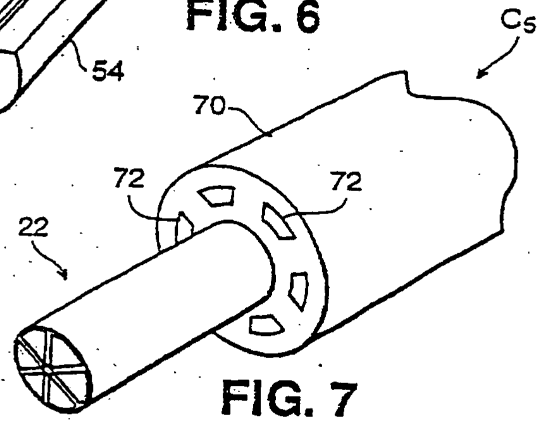

FIG. 7

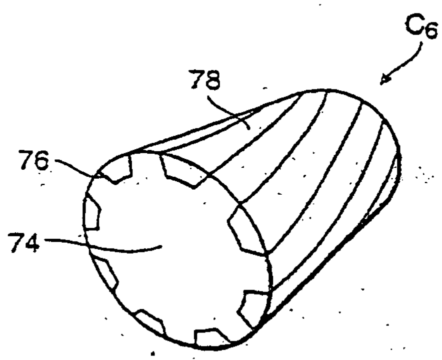

FIG. 8

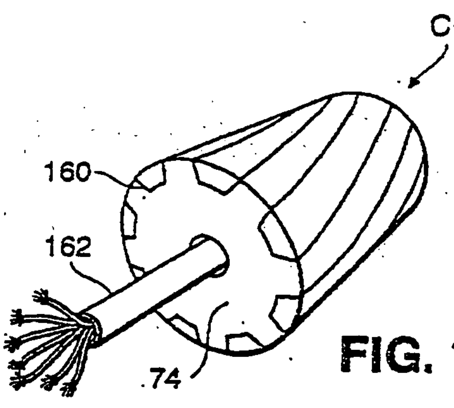

FIG. 16

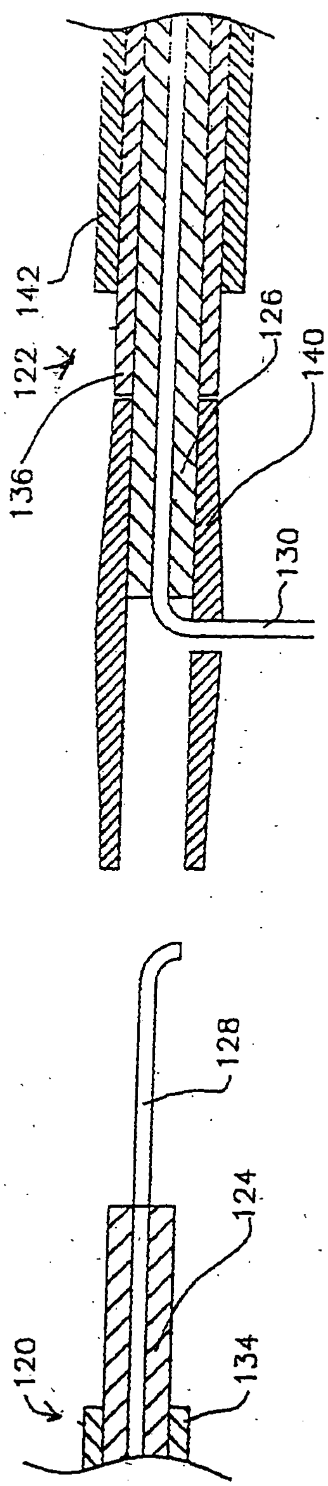

FIG. 9

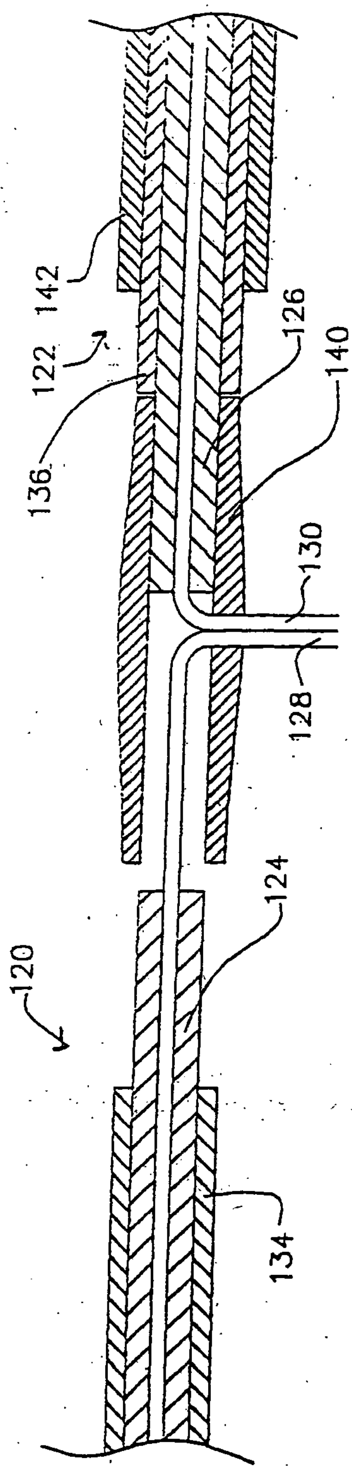

FIG. 10

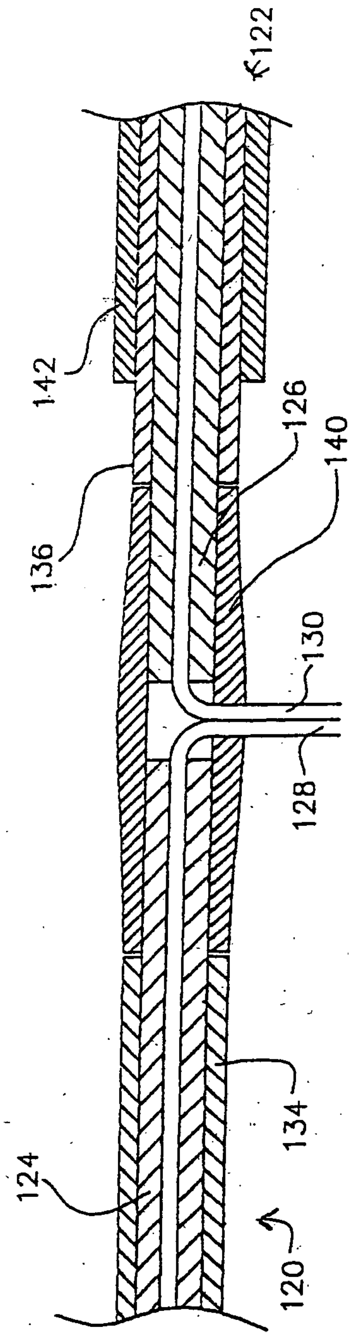

FIG. 11

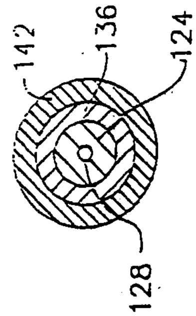

FIG. 13

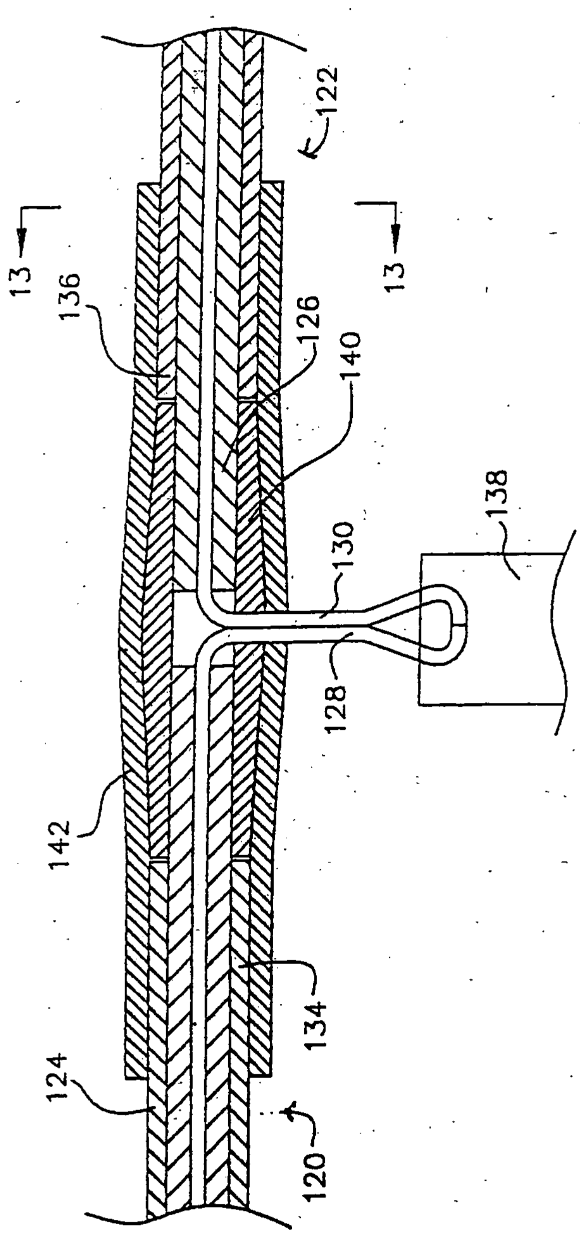

FIG. 12

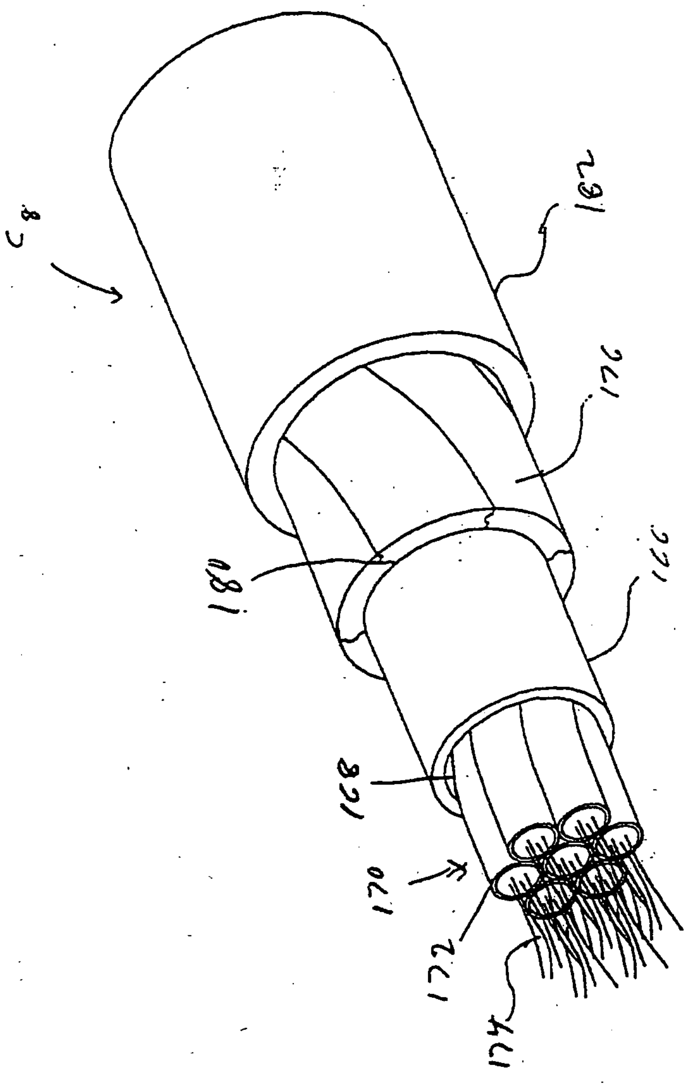

FIG. 14

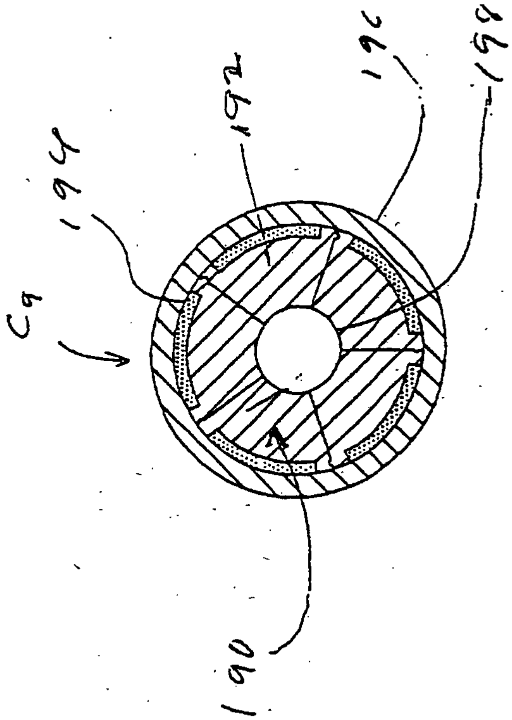

FIG. 15